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# *Indian Standard*
# APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR ac SYSTEMS
## PART IV THERMAL RELAYS

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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# Indian Standard

# APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR ac SYSTEMS

## PART IV THERMAL RELAYS

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# *Indian Standard*

# APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR ac SYSTEMS

## PART IV THERMAL RELAYS

## 0. FOREWORD

**0.1** This Indian Standard ( Part IV ) was adopted by the Indian Standards Institution on 21 November 1966, after the draft finalized by the Relays Sectional Committee had been approved by the Electrotechnical Division Council.

**0.2** Modern power systems are designed to provide uninterrupted electrical supply, yet the possibility of failure cannot be ruled out. The protective relays stand watch and in the event of failures, short-circuits or abnormal operating conditions help de-energize the unhealthy section of the power system and restrain interference with the remainder of it and thus limit damage to equipment and ensure safety of personnel. They are also used to indicate the type and location of failure so as to assess the effectiveness of the protective schemes.

**0.3** The features which the protective relays should possess are:

a) reliability, that is, to ensure correct action even after long periods of inactivity and also offer repeated operations under severe conditions;

b) selectivity, that is, to ensure that only the unhealthy part of the system is disconnected;

c) sensitivity, that is, detection of the short circuit or abnormal operating condition;

d) speed to prevent or minimize damage and risk of instability of rotating plant; and

e) stability, that is, the ability to operate only under those conditions that call for its operation and to remain either passive or biased against operation under all other conditions.

**0.4** Thermal relays are generally applied for overload protection of electrical apparatus where maximum utilization of their thermal withstand capabilities is desired. However, they have certain inherent qualities which enable them to detect certain abnormal conditions as well. Certain unbalanced conditions, such as unbalanced voltages or currents cause additional heating effects in some dynamic electrical apparatus, namely, rotating

machines. Applications of phase unbalance relays are covered in detail in Part III of this guide. Thus thermal protection of such apparatus is complete only when full consideration is given to these additional heating effects.

**0.5** This guide deals with those relays only which are covered by IS : 3231-1965*.

**0.6** This guide has been prepared mainly to assist protection engineers in the application of thermal relays. Few practical examples have also been included to illustrate the application of these relays, settings, etc. However, it is emphasized that this guide has been prepared to assist rather than to specify the relays to be used. This guide deals only with the principles of application of thermal relays and does not deal with the selection of any particular protective scheme. The actual circuit conditions in all probability may be different from those given here. The examples, even though drawn from actual field applications, should be regarded as mere illustration of one or the other point.

**0.7** In the preparation of this guide considerable assistance has been derived from several published books and from manufacturers' trade literature. Assistance has also been rendered by State Electricity Boards in collecting actual examples.

**0.8** This guide is one of the series of Indian Standard application guides for electrical relays for ac systems. The other guides in this series are:

IS : 3638-1966 Application guide for gas-operated relays

IS : 3842 ( Part I )-1967 Application guide for electrical relays for ac systems : Part I Overcurrent relays for feeders and transformers.

IS : 3842 ( Part II )-1966 Application guide for electrical relays for ac systems : Part II Overcurrent relays for generators and motors.

IS : 3842 ( Part III )-1966 Application guide for electrical relays for ac systems : Part III Phase unbalance relays including negative phase sequence relays.

## 1. SCOPE

**1.1** This guide ( Part IV ) deals with application of thermal relays for ac systems covered by IS : 3231-1965*.

**1.2** This guide does not cover:

a) the principles of system design and system protection, and

b) application of such relays which form an integral part of a motor starter.

*Specification for electrical relays for power system protection.

## 2. TERMINOLOGY

2.1 For the purpose of this guide the definitions given in IS : 1885 ( Part IX )-1966* and those given in Part I of this guide shall apply.

## 3. TYPES OF THERMAL RELAYS

3.0 There are two types of thermal relays available:

a) Bimetallic relays, and

b) Heat sink type relays.

### 3.1 Bimetallic Relays

3.1.1 These consist essentially of one or more bimetallic elements heated either directly or indirectly by the line current or currents or a replica thereof, flowing into the protected apparatus. Figure 1 shows a bimetallic relay movement. On the occurrence of an overload the bimetallic strip or strips get heated up, their temperatures rising above normal, and bend, pushing the common trip bar in the tripping direction. The rate of heating determines the rate of movement and hence the tripping time, giving an inverse time characteristic.

3.1.2 The bimetallic elements work in unison on a common mechanism which operates one or more electrically separate contact-pair to give trip and alarm signals either directly or through an auxiliary relay. The mechanism is so designed that either an increase in the line currents, or a difference in the line currents ( amounting to an 'unbalance ) drives the mechanism towards the ' operate ' direction. The setting is normally varied by adjusting the contact traverse or by having a tapped saturating transformer between the main current transformers and the thermal elements. The sensitivity to different currents gives it an inherent single phasing or unbalance detection features.

3.1.3 In the relays provided with single phasing and unbalance protection, the common tripping mechanism is driven towards the tripping direction on the principle of difference of current. Under these conditions the operating time depends on the difference in the line currents, which cause different degrees of deflection in the three bimetallic strips. This is not a true replica of the thermal conditions inside the motor, and the motor may be tripped out long before it reaches its thermal limit for unbalances during light load conditions. This type of relay, however, gives a fairly true thermal image of the motor under balanced condition.

3.1.4 It is possible on these relays to have an instantaneous or time delayed overload feature. This enables large disturbance currents to be cleared instantaneously.

*Electrotechnical vocabulary : Part IX Electrical relays.

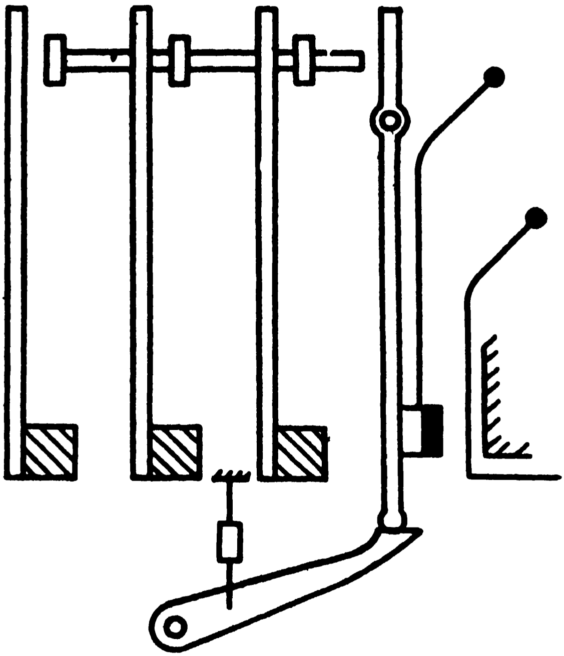


FIG. 1 A TYPICAL BIMETALLIC RELAY

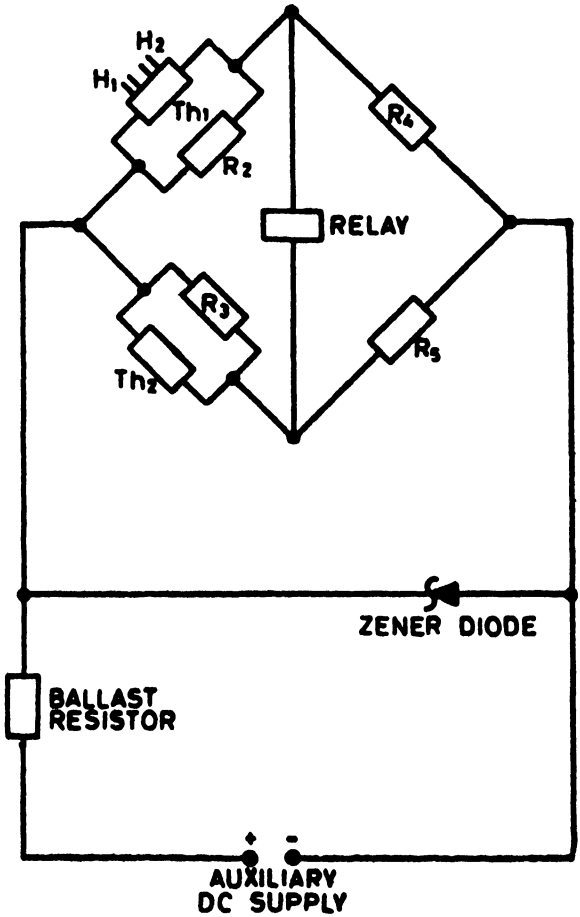
**3.1.5** Temperature compensation for ambient temperature is incorporated either in the bimetallic elements themselves or in a separate compensation unit.

**3.2 Heat Sink Type Relays**

**3.2.1** In this type of relay, the thermal element or image is a thermistor instead of a bimetallic strip. The heat sink thermistor forms one arm of a sensitive balanced Wheatstone bridge and a temperature compensation thermistor forms another. The heat sink thermistor is heated by either the line currents or their derivatives. The change in resistance of the heat sink thermistor gives a signal across the output terminals of the bridge circuit. This is used to operate another relay which gives the trip and alarm signals.

**3.2.2** Figure 2 shows a heat sink relay thermal element. $Th_1$ is the heat sink thermistor, $Th_2$ the ambient temperature compensation thermistor and $R_2$, $R_3$, $R_4$ and $R_5$ are the balancing resistors. The two heaters $H_1$ and $H_2$, fed by positive and negative sequence components of the line current

respectively, operate on the heat sink thermistor. Unbalance in the bridge circuit and hence operation is caused when the resistance of the thermistor is changed due to the combined heating of the two heaters, and the voltage across the relay exceeds the setting value of the relay. The operating time depends on the rate of heat input to $Th_1$ and consequently on the amount of overload, giving the inverse time characteristic.




$H_1$ Heater energized by positive sequence filter

$H_2$ Heater energized by negative sequence filter

$Th_1$ Main thermistor

$Th_2$ Ambient temperature compensation thermistor

FIG. 2 A TYPICAL CIRCUIT DIAGRAM OF A HEAT SINK RELAY

**3.2.3** As the total heating effect of the positive and negative phase sequence currents are taken into account, a true thermal image of the motor is obtained even under unbalanced conditions. This ensures that the motor is tripped only when its thermal limits are likely to be stressed.

**3.2.4** Under light load conditions, even single phasing operation may be possible, as this does not endanger the motor. However, the relay invariably operates before the thermal limit is reached, and as this is the main criteria in motor protection, the motors may be fully protected under all conditions by a properly designed heat sink relay set to grade with the motor thermal limit characteristics. Heat sink relays normally permit a greater utilization of motor thermal capabilities.

**3.2.5** The additional heating effect due to unbalance currents or single phasing, in rotating machines is a result of the double frequency currents induced in the rotor circuit due to the presence of negative phase sequence currents in the stator circuit. The effect of single phasing and unbalance is best catered for in a heat sink type relay by breaking up the line currents in their sequence components and impressing the heating effects of each component separately on to the heat sink. This also enables a closer match of relay and machine thermal withstand characteristics than it is possible to achieve in the bimetallic relays.

**3.2.6** This type of relay usually provides high set units for both positive and negative sequence currents ensuring instantaneous tripping under large balanced currents or large unbalances in the system and motor.

**3.2.7** Both the bimetallic and heat sink type relays may be provided with a sensitive earthfault protection, usually in the form of a separate relay connected across a zero sequence filter.

**3.2.8** Comparison of thermal characteristics of bimetallic and heat sink relays is given in Fig. 3.

## 4. INFORMATION REQUIRED FOR APPLICATION OF THERMAL RELAYS

**4.1** The following information will assist in the correct application of thermal relays:

a) Thermal withstand characteristics of apparatus for which thermal relays are being used;

b) Starting characteristics ( in case of dynamic apparatus, such as motors ) in the form of time-current characteristic;

c) Current transformer ratio;

d) Relay particulars, that is, setting range, characteristics, relay thermal limit and tolerances;

e) Maximum fault current available at relaying point; and

f) Ambient conditions.

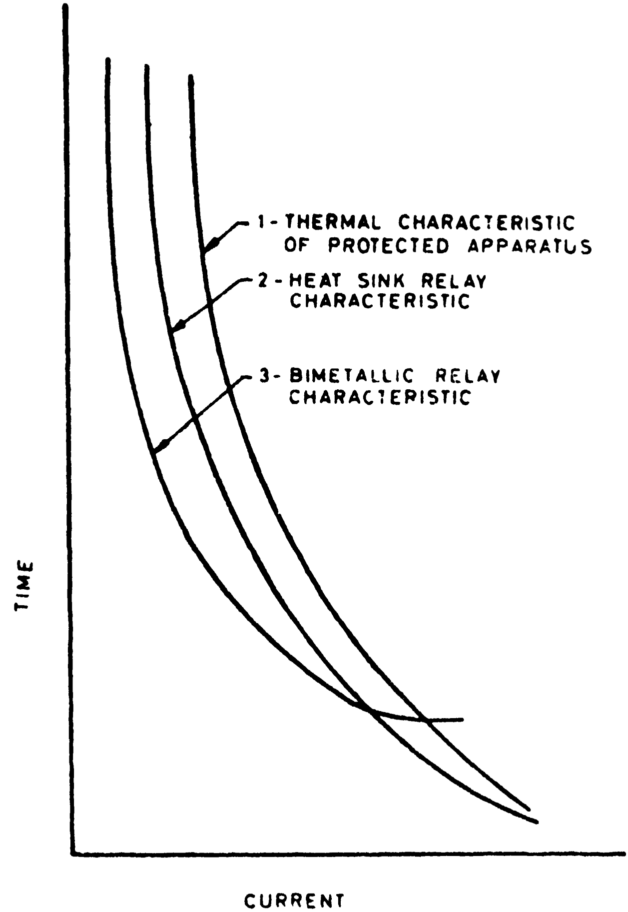



FIG 3 COMPARISON OF THERMAL CHARACTERISTICS OF BIMETALLIC AND HEAT SINK THERMAL RELAYS

## 5. STEPS TO CHECK CORRECT APPLICATION THERMAL WITHSTAND CHARACTERISTIC AVAILABLE

**5.1** When the thermal withstand characteristic of the apparatus to be protected is available, the setting procedure is as follows:

a) Plot the thermal withstand characteristic of the apparatus to be protected on a graph with time as ordinate and current as abscissa

b) Choose a suitable relay setting such that the relay inverse time characteristic lies just below the thermal withstand characteristic of the protected apparatus as shown in Fig. 4. This gives overload matching. In this operation normally the hot characteristic curve of the thermal relays is used.

c) Draw the starting characteristic of the apparatus ( if dynamic ). This would normally lie below the relay 'hot' curve if the latter is closely matched to the motor thermal withstand characteristic.

d) If the starting characteristic crosses the 'hot' curve of the relay, then the 'cold' curve of the relay should be drawn and set to lie as

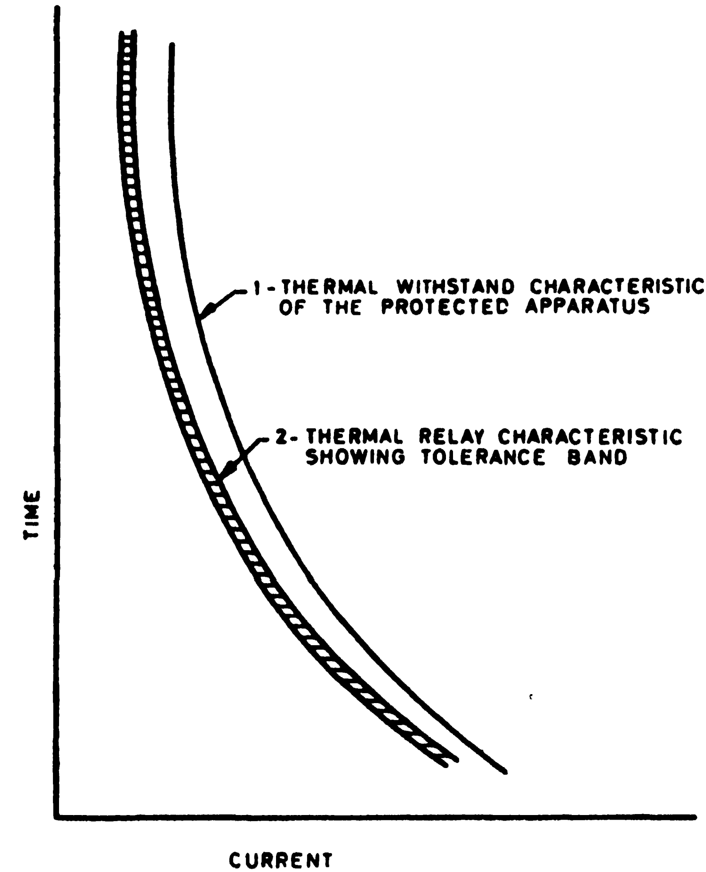



Fig. 4 Matching of Relay Characteristic and Thermal Withstand Characteristic of Protected Apparatus

far above the starting characteristic as possible, bearing in mind that the relay 'hot' curve should match the thermal withstand characteristic of the protected apparatus.

e) Check the fault current available and compare it with the thermal limit of the relay. If the fault current exceeds the thermal limit use a high set instantaneous unit. This also limits damage due to heavy faults.

f) The high set instantaneous unit should be set such that it does not *trip the motor while starting.*

NOTE — Although the motor may have a nominal starting current of say six times the normal full load current, the first half cycle peak current may be many times this value. It may be necessary, therefore, depending upon the design of the instantaneous relay, to set the relay to a considerably higher value than the steady state starting current.

## 6. STEPS TO CHECK CORRECT APPLICATION — THERMAL WITHSTAND CHARACTERISTIC NOT AVAILABLE

**6.1** When the thermal withstand characteristic of the apparatus to be protected is not available, the setting procedure is as follows.

**6.1.1** *Dynamic Apparatus*

a) Plot the starting characteristic on a graph.
b) Set the relay 'hot' curve to lie wholly above the former.
c) Where the maximum setting of 'hot' curve crosses the starting characteristic ( which may happen due to unmatched current transformer ratios ), set the 'cold' curve of the relay as far above the starting characteristic as possible.

Both **6.1.1**(b) and **6.1.1**(c) give approximate matching of thermal withstand characteristic of the machines.

**6.1.2** *Static Apparatus* — The manufacturers of static apparatus may be consulted for exact settings.

**6.1.3** Another approach is to assume a certain continuous overload capability of the apparatus ( whether static or dynamic ) and to set the relay to pick-up above this value. In the case of dynamic apparatus the 'cold' curve for this setting is also drawn and a check to see that the starting characteristic lies below this, is made.

**6.1.4** *High Set Unit Setting* — The high set unit should be set to cover the starting characteristic ( in case of dynamic apparatus ) and below the thermal limit of the relay, if the latter is likely to be exceeded by the fault levels at the relaying point. It is also useful for grading purposes where the relay characteristics are flatter than the back-up relays ( as is usually the case ).

NOTE — The relay is very often automatically protected against heavy overloads because of current transformer saturation which limits the maximum available secondary fault current.

## 7. SETTING OF SINGLE PHASING UNIT

**7.1** The setting of single phasing unit is fixed by the design of the mechanism in the case of bimetallic relays and depends on the actual load current flowing in the relay. The setting of single phasing detection device in the case of heat sink type relays is usually adjusted at the design stage, but is a function of the overload setting subsequently. The instantaneous unit of the negative phase sequence circuit, incorporated in the heat sink relays, is independently adjustable.

## 8. OPERATING CURRENT

**8.1** The operating current of bimetallic thermal relays is usually 100 percent of the setting. The operating current of heat sink relays varies, and is of the order of 110 percent of the setting. This should be considered while working out the setting of the relays.

## 9. THERMAL RELAYS WITH LONG TIME CHARACTERISTICS

**9.1** Certain motors have a longer duration of starting and for these motors thermal relays with a large time delay are normally used. Thermal relays designed to cater for large starting time motors are also available.

## 10. EXAMPLES

**10.1** Examples of application of thermal relays to motors whose both starting and thermal withstand characteristics are available are given in Appendix A ( *see also* **5** ).

**10.2** Examples of application of thermal relays to motors whose only starting characteristics are available are given in Appendix B ( *see also* **6** ).

**10.3** Examples of application of thermal relays to continuously rated motors are given in Appendix C.

# APPENDIX A

( *Clause* 10.1 )

## APPLICATION OF THERMAL RELAYS TO A MOTOR WHOSE BOTH STARTING AND THERMAL WITHSTAND CHARACTERISTICS ARE GIVEN

### A-1. MOTOR CHARACTERISTICS

i) 450 kW, 3·3 kV, 3 phase, 50 cycles

ii) Direct on line starting

| | | |
|---|---|---|
| iii) | Starting current | 700 A for 3 seconds<br>500 A for the next 7 seconds |
| iv) | Full load current | 97 A |
| v) | Thermal withstand characteristic ( hot ) | *See* Fig. 5 |
| vi) | Current transformer ratio | 100/1 |
| vii) | Fault current available at 3·3 kV bus bar | 13·2 kA |

The approximate ( stepped ) starting characteristic is drawn on the same graph as the thermal withstand characteristic ( *see* Fig. 5 ).

## A-2. APPLICATION OF BIMETALLIC THERMAL RELAYS ( Fig. 5 )

Relay setting range — 80 to 125 percent ( continuously adjustable ).

Instantaneous high set unit setting — 8 to 14 times rated current.

$$\text{Relay tap} = \frac{\left(\begin{array}{c}\text{Effective operating}\\ \text{current in percent}\end{array}\right) \times \left(\begin{array}{c}\text{Motor full load}\\ \text{current in amperes}\end{array}\right)}{1 \times \left(\begin{array}{c}\text{Current trans-}\\ \text{former ratio}\end{array}\right) \times \left(\begin{array}{c}\text{Relay rating in}\\ \text{amperes}\end{array}\right)}$$

where the value '1' represents the operating current in per unit of the setting current ( *see* **8** ).

The relay 'hot' curve has to be fitted in between thermal withstand characteristic and the motor starting characteristic.

Trials reveal that a setting of 105 percent gives the best fitting characteristic.

A high set instantaneous unit setting of 8 times full load gives a characteristic of the relay which lies just below the thermal withstand characteristic.

## A-3. APPLICATION OF HEAT SINK THERMAL RELAYS

**A-3.1 Relay Characteristics** — Instantaneous unit setting range is 400 to 800 percent of relay setting ( continuously adjustable ).

Unbalance current setting range is derived from

$$I_{eq} = \sqrt{I_1^2 + 3 I_2^2}$$

where

$I_1$ and $I_2$ = positive and negative phase sequence currents respectively, and

$I_{eq}$ = equivalent current for deciding the setting.

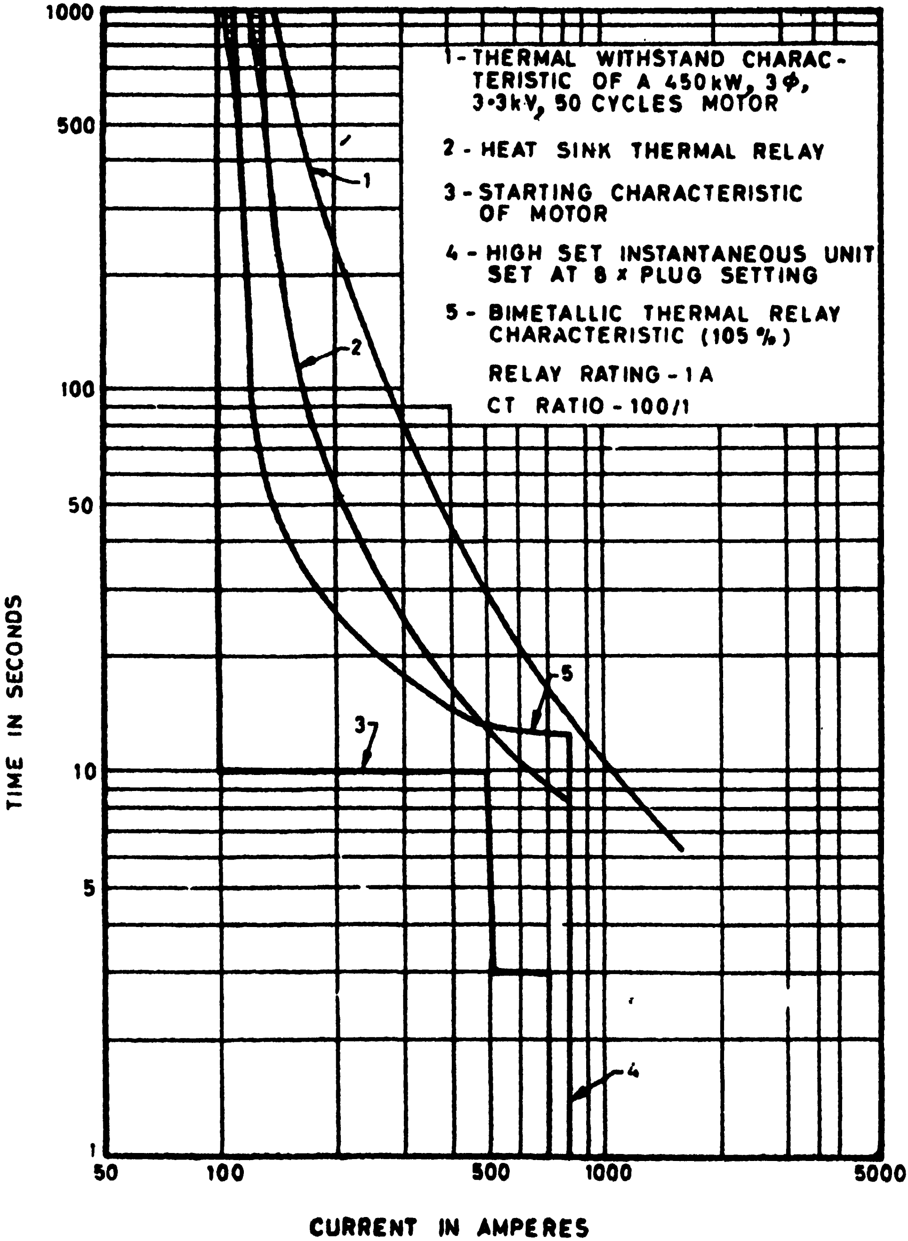



FIG. 5 APPLICATION OF THERMAL RELAYS TO MOTORS WHOSE BOTH STARTING AND THERMAL WITHSTAND CHARACTERISTICS ARE GIVEN

Negative phase sequence instantaneous unit setting range is 200 to 600 percent of relay setting ( continuously adjustable )

$$\text{Relay tap} = \frac{\begin{pmatrix}\text{Effective operating}\\ \text{current in percent}\end{pmatrix} \times \begin{pmatrix}\text{Motor full load}\\ \text{current in amperes}\end{pmatrix}}{1{\cdot}1 \times \begin{pmatrix}\text{Current trans-}\\ \text{former ratio}\end{pmatrix} \times \begin{pmatrix}\text{Relay rating in}\\ \text{amperes}\end{pmatrix}}$$

where the value '1·1' represents the operating current in per unit of the setting current ( *see* **8** ).

**A-3.2 Plug Setting** — The relay characteristic ( hot ) has to be fitted in between the thermal withstand characteristic and the motor starting characteristic.

A few trials reveal that in this instance a plug setting of 110 percent gives the characteristic curve 2 in Fig. 5. This is quite satisfactory.

The operating current setting is obtained from the expression

$$\begin{array}{l}\text{Effective}\\ \text{operating}\\ \text{current}\\ \text{( percent )}\end{array} = \frac{1{\cdot}1 \times \begin{pmatrix}\text{Relay tap}\\ \text{in percent}\end{pmatrix} \times \begin{pmatrix}\text{Current trans-}\\ \text{former ratio}\end{pmatrix} \times \begin{pmatrix}\text{Relay rating}\\ \text{in amperes}\end{pmatrix}}{\begin{pmatrix}\text{Motor full load}\\ \text{current in amperes}\end{pmatrix}}$$

$$= \frac{1{\cdot}1 \times 110 \times \frac{100}{1} \times 1}{97}$$

$$= 125 \text{ percent}$$

**A-3.3 Unbalance Setting** — As shown in Appendix B, the relay operates when the negative phase sequence current in the system reaches 26·5 percent of the positive sequence current ( *see* **B-3.2** ).

**A-3.4 Single Phasing Setting** — As shown in Appendix B, the relay operates on single phasing if the line current reaches 95 percent of setting current under these conditions ( *see* **B-3.3** ).

**A-3.5 Unbalance Current Instantaneous Unit Setting** — This is set at:

$$\tfrac{1}{3} \times \text{starting current}$$
$$= \tfrac{1}{3} \times 700$$
$$= 233 \text{ A}$$

A setting of about 220 percent is adequate.

With the settings given above, the motor is now fully protected.

A comparison of curves (2) and (5) shows that thermal capabilities of a motor are better utilized by heat sink relays, and that the bimetallic relays have a tendency to overprotect the motors.

# APPENDIX B

( *Clause* 10.2 )

## APPLICATION OF THERMAL RELAY TO A MOTOR WHOSE STARTING CHARACTERISTIC ONLY IS GIVEN

**B-1. MOTOR CHARACTERISTICS**

| | | |
|---|---|---|
| i) | 900 kW, 3·3 kV, 3 phase, 50 cycles | |
| ii) | Direct on line starting | |
| iii) | Starting current | 1 500 A for 2 seconds<br>1 200 A for the next 10·5 seconds |
| iv) | Full load current | 217 A |
| v) | Current transformer ratio | 300/5 |
| vi) | Fault current available at 3·3 kV bus bar | 13·2 kA |

The approximate starting characteristic ( stepped ) is drawn on the log-log graph with time as ordinate and current as abscissa ( *see* Fig. 6 and 7 ).

**B-2. APPLICATION OF BIMETALLIC THERMAL RELAY ( Fig. 6 )**

**B-2.1 Relay Characteristics**

Relay setting range is 80 to 125 percent ( continuously adjustable ).

Instantaneous high set unit setting is 8 to 11 times rated current.

$$\text{Relay tap} = \frac{\begin{pmatrix}\text{Effective operating}\\ \text{current in percent}\end{pmatrix} \times \begin{pmatrix}\text{Motor full load}\\ \text{current in amperes}\end{pmatrix}}{1 \times \begin{pmatrix}\text{Current trans-}\\ \text{former ratio}\end{pmatrix} \times \begin{pmatrix}\text{Relay rating}\\ \text{in amperes}\end{pmatrix}}$$

where the value '1' represents the operating current in per unit of the setting current ( *see* **8** ).

Assuming the effective operating current of 125 percent of full load current:

$$\text{Relay tap} = \frac{125 \times 217}{1 \times \frac{300}{5} \times 5}$$

$= 90·6$ percent

$= 90$ percent giving an effective operating current slightly less than 125 percent

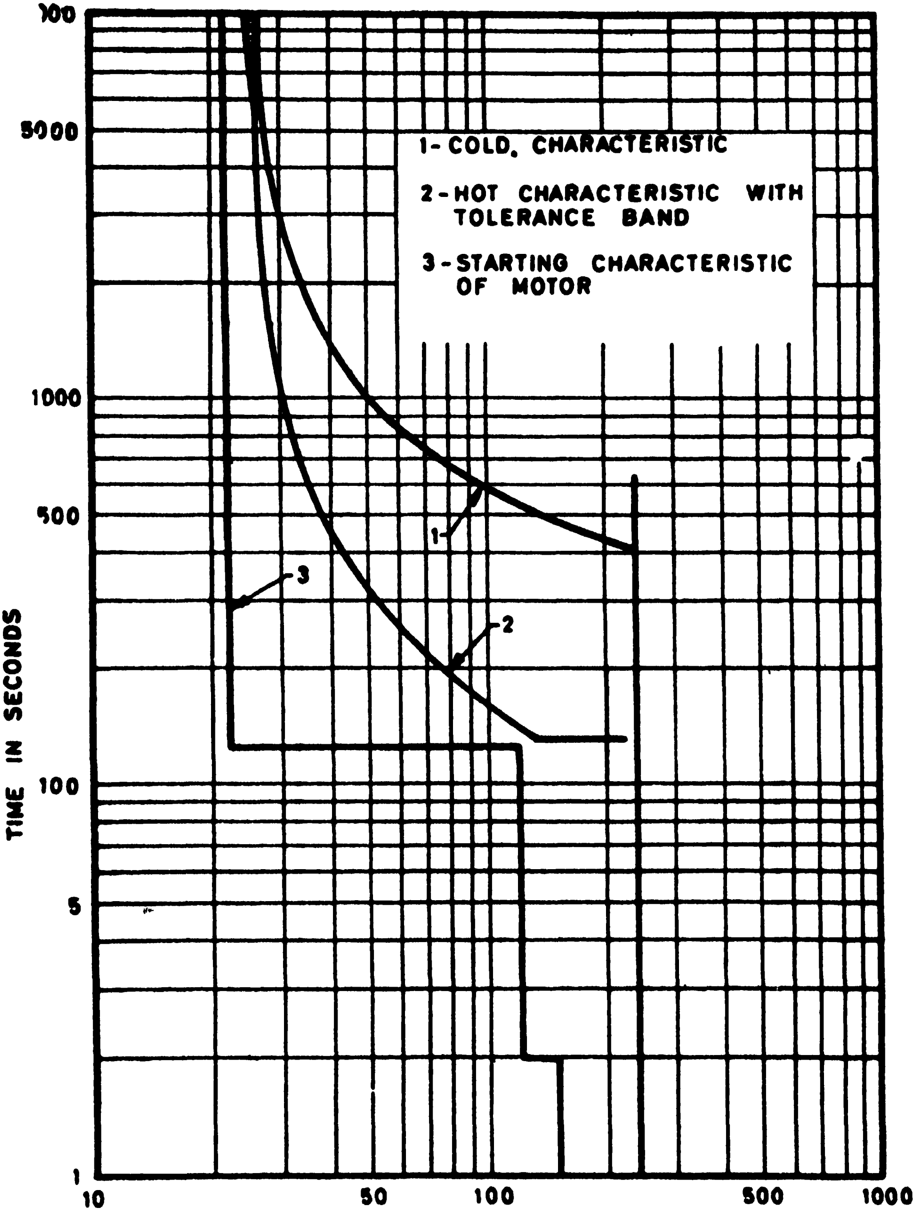



FIG. 6 APPLICATION OF BIMETALLIC THERMAL RELAY

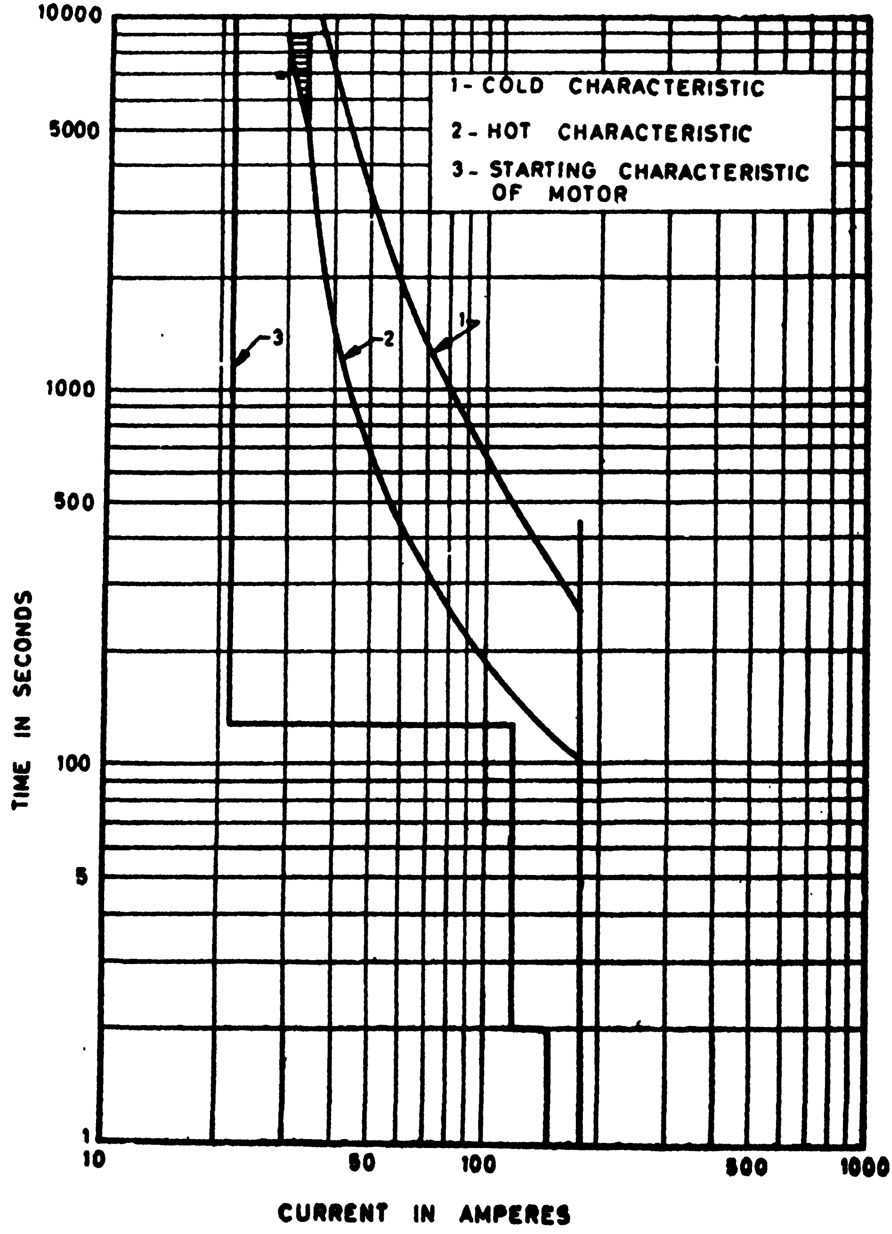



Fig. 7 Application of Heat Sink Thermal Relay

The 'hot' and 'cold' characteristics are drawn with this setting. The 'hot' curve with its tolerance band of $\pm 3$ percent on current lies wholly above the starting characteristic.

The high set unit is given the lowest setting and clears the starting current and lies well below the maximum available fault current.

The relay should give approximate matching with the thermal withstand characteristic.

**B-3. APPLICATION OF HEAT SINK THERMAL RELAYS ( Fig. 7 )**

Relay setting range is 70 to 130 percent ( in seven steps ).

Instantaneous unit setting range is 400 to 800 percent of relay setting.

Unbalance current setting range is derived from:

$$I_{eq} = \sqrt{I_1^2 + 3I_2^2}$$

where

$I_1$ and $I_2$ = positive and negative phase sequence currents respectively, and

$I_{eq}$ = the equivalent current for deciding the setting.

Negative phase sequence instantaneous unit setting range is 200 to 600 percent of relay setting.

$$\text{Relay tap} = \frac{\left(\begin{array}{c}\text{Effective operating}\\ \text{current in percent}\end{array}\right) \times \left(\begin{array}{c}\text{Motor full load}\\ \text{current in amperes}\end{array}\right)}{1{\cdot}1 \times \left(\begin{array}{c}\text{Current trans-}\\ \text{former ratio}\end{array}\right) \times \left(\begin{array}{c}\text{Relay rating in}\\ \text{amperes}\end{array}\right)}$$

where the value of '1·1' represents the operating current in per unit of the setting current mentioned in 8.

Assuming the effective operating current of 125 percent of full load current:

$$\text{Relay tap} = \frac{125 \times 217 \times 5}{1{\cdot}1 \times 300 \times 5}$$

$= 82{\cdot}5$ percent

$= 90$ percent, giving an effective operating current of 136 percent.

The 90 percent 'hot' curve fouls with the setting characteristic.

Assuming that the motor follows a rapid start-stop cycle after a long run period, it is necessary to ensure that the relay ' hot ' curve lies wholly above the starting characteristic. This may be achieved by a relay setting of 100 percent, giving an effective operating current of 151 percent. This value may be high for motor continuously rated for or near maximum output, but is quite in order for motors having a large overload capacity.

In such cases of doubt, however, it is best to call for the thermal withstand characteristics of the motors and to ensure that the relay characteristic ' hot ' curve lies below it.

It may be noted that higher effective operating current setting of heat sink relays may be adopted without exceeding the thermal limit of the protected apparatus because of the closer match obtained between the characteristics of this type of relay and the thermal withstand characteristic of the protected apparatus. This enables the thermal capacity of the apparatus to be fully utilized.

**B-3.1 Instantaneous Element Setting** — Instantaneous element setting of 600 percent of relay setting ( 100 percent ) covers the starting characteristic and limits the fault current to 1 800 A.

**B-3.2 Unbalance Setting** — The equivalent operating current is:

$$= 110 \text{ percent}$$

$$= \sqrt{I_1^2 + n I_2^2}$$

where

$I_1$ = positive phase sequence current, and

$I_2$ = negative phase sequence current.

The negative phase sequence current $I_2$, as a percent of positive phase sequence current that will cause the relay to operate, is given by:

$$I_2^2 = \frac{110^2 - I_1^2}{n}$$

$$\therefore \quad I_2 = \sqrt{\frac{110^2 - I_1^2}{n}}$$

Putting $n = 3$, as given in relay characteristic:

$$I_2 = \sqrt{\frac{110^2 \quad 100^2}{3}}$$

$$= 26{\cdot}5 \text{ percent of the setting current.}$$

The relay will, therefore, operate when the negative phase sequence component, is about 26·5 percent of the setting current.

**B-3.3 Single Phasing Setting** — Under single phasing conditions $I_1 = I_2$

$$\therefore \quad 110 = \sqrt{I_1^2 + 3I_1^2}$$

or $I_1 = \frac{110}{2} = 55$ percent of setting current.

The total single phase line current is:

$$= \sqrt{3} \times I_1$$
$$= \sqrt{3} \times 55 \text{ percent}$$
$$= 95 \text{ percent of setting current}$$

NOTE — The single phase line current under normal operating conditions will increase above the three-phase balanced current if the machine load is to be maintained.

**B-3.4 Unbalance Current Instantaneous Unit** — This is normally set at about:

$$\tfrac{1}{3} \times \text{starting current}$$
$$= \tfrac{1}{3} \times 1\,500$$
$$= 500 \text{ A}$$

Thus a setting of 200 percent will suffice giving an instantaneous setting of 600 A.

## APPENDIX C

( *Clause* 10.3 )

### APPLICATION OF THERMAL RELAYS TO CONTINUOUS RATED MOTORS

### C-1. GENERAL

**C-1.1** Thermal withstand characteristics of these motors are such that they do not permit thermal relays to give any overload protection, if their rated capacity is to be utilized. The only method of providing any protection in the overload region of the thermal withstand characteristics of the motor, is by the use of:

a) thermistors embedded in the stator and rotor windings and connected in a sensitive bridge circuit to give an output signal, for temperature-rise approaching withstand value, to take the motor off load; or

b) thermocouples embedded in the stator and rotor windings and their signals amplified to give an output of temperature-rise approaching withstand value to take the motor off load.

**C-1.2** Thermal relays are still used with these motors for protection against unbalanced conditions, single phasing and other faults, as they are one of the cheapest form of comprehensive protection.

**C-1.3** Where these motors are not utilized to their full capacity, reduced settings on the thermal relays may sometimes give full protection against overloads, faults or unbalanced conditions.

## C-2. EXAMPLE

### C-2.1 Application of Heat Sink Thermal Relay

**C-2.1.1** *Motor Characteristics*

i) 110 kW, 3·3 kV, 3 phase, 50 cycles, continuous rated motor, direct on line starting

| | | |
|---|---|---|
| ii) | Starting current | 157·5 A for less than 1 second |
| iii) | Full load current | 26·2 A ( approximately ) |
| iv) | Current transformer ratio | 150/5 |

Thermal withstand characteristic ( hot ) is shown in Fig. 8.

**C-2.1.2** *Relay Characteristics** — Relay characteristics are same as given in **A-3.1.** Rating used is 1A although 5A current transformers are used, to get the setting within the relay range.

**C-2.1.3** *Plug Setting* — Plug setting of 80 percent gives an operating current of 100·6 percent of full load current. With this the motor is unprotected for overloads between 100 to 130 percent of full load lasting for more than about 300 seconds. For overloads beyond this value, or less than this time, the motor is protected by the relay.

Plug setting of 70 percent gives an operating current of 88 percent of full load current. Thus with this setting the motor cannot utilize its rated capacity. On the other hand the protected zone is increased and the motor is safe except for overloads between 100 to 110 percent lasting for more than 350 seconds.

**C-2.1.4** *Instantaneous Unit Setting* — A setting of 8 times plug setting keeps the relay characteristic for both plug settings below the thermal withstand characteristic of the motor.

**C-2.1.5** *Unbalance and Single Phasing Setting* — Unbalance settings and single phasing settings are the same as for heat sink relay given in **A-3.**

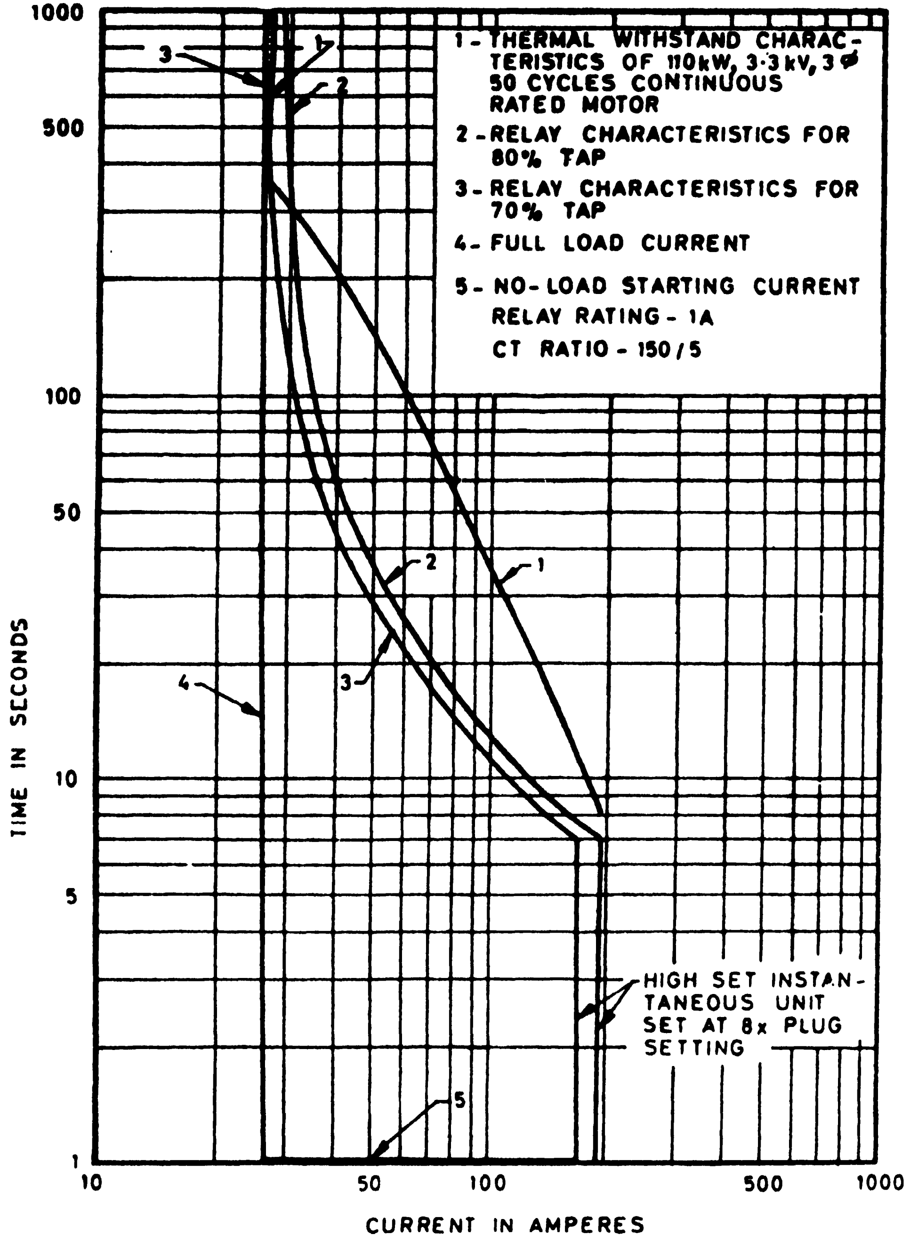



FIG. 8 APPLICATION OF THERMAL RELAYS TO CONTINUOUS RATED MOTORS

**C-2.1.6** *Negative Phase Sequence Instantaneous Unit Setting*

$$\text{Setting} = \tfrac{1}{3} \times \text{starting current}$$
$$= \tfrac{1}{3} \times 157{\cdot}5$$
$$= 52{\cdot}5 \text{ A}$$

This requires a setting of 220 percent for 80 percent plug setting and 250 percent for 70 percent plug setting.

**C-2.2** This example has been specially chosen from a practical problem. The current transformers do not match the full load current of the motor and as a result a 1A relay has to be used with the 5A current transformer secondary to bring the operating current within the setting range of the relay, with the existing 150/5 ratio current transformers. This practice is not normally recommended as it requires very large ratio current transformers, resulting in higher primary fault settings. An endeavour should always be made to get current transformers to match the full load current as closely as possible. An ideal current transformer for this particular application would be of ratio 30/1.

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Telephones: 323 0131, 323 3375, 323 9402 Fax :+ 91 011 3234062, 3239399, 3239382
E - mail : bis@vsnl.com. Internet : http://wwwdel.vsnl.net.in/bis.org

| ***Central Laboratory*:** | ***Telephone*** |
|---|---|
| Plot No. 20/9, Site IV, Sahibabad Industrial Area, Sahibabad 201010 | 77 00 32 |
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|---|---|
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